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Comparison of associations between maternal peri-pregnancy with paternal anthropometrics on child anthropometrics from birth through age 7 years assessed in The Danish National Birth Cohort

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Abbreviations:

BMI; weight/height^2 kg/m^2

DNBC; The Danish National Birth Cohort

DXA; Dual-energy X-ray absorptiometry

SD; Standard Deviation

ABSTRACT

Background: Maternal pre-pregnancy adiposity may influence child adiposity beyond the transmitted genetic effects, which, if true, may accelerate the obesity epidemic, but the evidence for this mechanism is inconsistent.

Objective: To assess whether the associations of maternal body mass index (BMI; weight/height^2 kg/m^2) with child anthropometrics from birth, through infancy and at 7 years of age exceed those of paternal associations.

Design and analyses: In the Danish National Birth Cohort, information on parental and child anthropometrics is available for 30,655 trio families from maternal interviews during pregnancy and the postpartum period and from a 7 year follow-up. Using multiple linear and logistic regression models of child standard deviation (z)-scores of weight and BMI at birth, 5 months, 12 months, and 7 years, and of child overweight at age 7 years, we compared associations with maternal pre-pregnancy and post-partum BMI z-scores and with paternal BMI z-scores.

Results: Comparing maternal-child and paternal-child BMI z-score associations, strongest associations were observed with mothers' BMI at birth (0.143 (95% CI: 0.130,0.155) per maternal BMI z-score, and 0.017 BMI z-scores (CI: 0.005,0.029) per paternal BMI z-score), and throughout infancy, but the relative difference in the associations declined by child age (for BMI z-score at child age 7 years: 0.208 (CI: 0.196,0.220) per maternal BMI z-score, and 0.154 (CI: 0.143,0.166) per paternal BMI z-score). At 7 years of age the odds ratios of child overweight were 2.30 (CI: 1.99, 2.67) by maternal overweight and 1.96 (CI: 1.74, 2.21) by paternal overweight. There were no differences between the results based on maternal BMI before and after pregnancy or on children's weight adjusted for length or height.

Conclusion: The associations of child weight and BMI with maternal BMI were stronger than with paternal BMI. Associations between maternal and child anthropometrics were strong at birth, but declined with child ageing.

Keywords:

Intrauterine environment, intergenerational relations, parental BMI, parental overweight, child anthropometry, childhood overweight, maternal effects

INTRODUCTION

Infant growth and the development of overweight in childhood are influenced by genetic, environmental, and stochastic factors. It has been suggested that the particular maternal environment provided during pregnancy and the early postpartum period by obese mothers may have lasting effects on the child's adiposity (1;2). If this mechanism makes the next generation of mothers more obese, then this may have contributed to boosting the obesity epidemic (1;2). The challenge is to distinguish such effects from those implicit in the transmission of the well-established genetic influence on adiposity (3). A variety of epidemiological tools are available to support this distinction (4). Comparison of the association between maternal phenotype (before, during and after pregnancy) and the child phenotype with the association between paternal phenotype and child phenotype is particularly useful in this regard (4).

This method has been used to assess the specific maternal associations with the body mass index (BMI; weight/height^2 kg/m^2) on the children's adiposity measures in a number of cohort studies (1;5-10) . A systematic review of these studies found that the studies suffered from various limitations and were too heterogeneous to be included in a meta-analysis (11) . Although the results of the studies were inconsistent, the overall conclusion from the review was that there was only limited evidence supporting the presence of specific maternal effects (11). Since then a very large Norwegian birth cohort study has corroborated this conclusion by indicating no specific maternal associations between her pre-pregnancy BMI and the child BMI at age 2-3 years (12). Several studies using the maternal phenotype at other times of her life than around pregnancy have in general not shown stronger relationships than with the paternal phenotype (13-18).

In the present large Danish birth cohort study we aimed to test the hypothesis that maternal and paternal anthropometry have equal associations with infant and child anthropometry measures. We

extend from previous analyses by including pre-pregnancy and postpartum maternal BMI and child adiposity measures from birth, during infancy through 7 years of age (weight adjusted for length or height, BMI, and at 7 year, waist circumference), and we added corresponding analyses of body length or height.

POPULATION AND METHODS

Study Population

For this study we used data from the Danish National Birth Cohort, which originally enrolled 92,274 mothers with 100,418 pregnancies from 1996 to 2002. The cohort is described in detail elsewhere (19). Briefly, the women were recruited from all over Denmark at the beginning of their pregnancy by their general practitioner. The women were interviewed twice during pregnancy at approximately week 16 and week 30, respectively (Interview 1 and Interview 2) and approximately 6 and 18 months postpartum (Interview 3 and Interview 4). Children were followed up at 7 years of age (mean follow-up time 7.04 years) by a mailed or web-based questionnaire filled in by the parents. All questionnaires used are available in English at www.dnbc.dk (20). Parents were asked to fill in the child's latest measured weight, height, and waist circumference as well as the settings and dates of these measurements. This information was available for 53,854 children, pertaining to ages from 4.5 through 9 years, the range indicating that some parents reported past measurements whereas other parents were delayed in answering the questionnaire. In the present study, we included live-born singletons, born at 37–43 weeks of gestation (n=50,387) with information on child's weight and height reported at the 7 year follow-up (n=48,312). However, only those with height and weight measures obtained between 5–8.5 y were included (n=48,218). In addition, the following exclusion criteria were applied: no maternal participation in Interview 1 (n=1,952); maternal type I diabetes, gestational diabetes or preeclampsia (n=1,402); missing information on maternal (n=659) or paternal BMI (n=9,233), and more than 30 days between children's weight and

height measurements (n=2,218). If mothers participated with more than one pregnancy, only the first pregnancy was included in the analyses, (n=2,188) to avoid non-independent observations. The final study population included 30,566 trio families (**Supplemental figure 1**).

Exposure variables

Maternal pre-pregnancy BMI, calculated from height and weight information obtained at Interview 1 (conducted in gestational week ~16), and paternal BMI calculated from height and weight information obtained from Interview 4 (conducted ~18 months postpartum), were the main exposures used for comparison of anthropometric associations. Paternal height (in meters) and weight (in kilos) was reported by the mother. Maternal and paternal heights were also used as individual exposures in relation to infant birth length and height at the 7-year follow-up. Maternal postpartum weight information, obtained at the same time as the paternal height and weight (Interview 4), was used in additional analyses as the exposure of interest for comparison with both maternal pre-pregnancy BMI and paternal BMI. Parental BMIs were utilised both as continuous variables and by five group-based categories according to the World Health Organization (underweight with BMI<18.5 kg/m^2, normal weight with BMI of 18.5≥–<25 kg/m^2, overweight with BMI ≥ 25–<30 kg/m^2, obese with BMI ≥ 30–<35 kg/m^2, and extremely obese with BMI ≥ 35 kg/m^2). A variable of four groups of combined parental normal weight (not including underweight) and overweight (including all with BMI ≥ 25 kg/m^2) was generated:1) both parents normal weight 2) mother normal weight/father overweight 3) mother overweight/father normal weight 4) both parents overweight.

Covariates

Information on mother's age at conception, parity, smoking during pregnancy and socio-economic status were obtained from Interview 1. Maternal age was included as a continuous variable in the analyses. Parity was categorized as primi- or multiparous, and smoking during pregnancy as non-

smoker, 1–10 cigarettes/day, and ≥10 cigarettes/day. Socioeconomic status was based on information on the mother's education and occupation and was classified as low, middle, or high status. Information on the mother's total gestational weight gain in kg was obtained from Interview 3, and was used as a continuous covariate. We deliberately avoided inclusion of covariates that could be considered as mediators of the effects of parental anthropometry on child anthropometry, e.g. breast feeding, which may be reduced in obese mothers and thereby associated with obesity in the children.

Outcome variables

The main outcome variable was childhood BMI at 7 years of age, used both as a continuous and a dichotomous variable. The latter was defined by International Obesity Task Force sex- and age-specific overweight criteria (21). Since only 2% of the children were classified as obese, we collapsed this group with the overweight group. Other outcomes were the child's weight (adjusted for height), height or length (adjusted for weight) and BMI at birth, at 5 months, at 12 months and at 7 years of age, and waist circumference at 7 years of age. Information about weight and length at birth was obtained from the National Birth Register. In Interview 4, the mothers reported the weight and length of the children at 5 months and 12 months of age measured either by the general practitioner or by the public health nurse. Information on weight, height, and waist at the 7-year follow-up was primarily reported by the mother. For 33% of the children the mothers reported the measures taken either by the school doctor, public health nurses, or general practitioners. For the remaining 67%, measures were taken by one of the parents. The reported measurements at age 7 years have been compared to measures of height and weight in a sub-sample of 1,122 children measured by a school doctor. This validation showed that the percentage of children categorised as overweight was slightly lower in the DNBC compared to the school doctor measurements. However, the validation showed no trend towards increasing differences of weight or height with

increasing averages of weight or height between the measurements from school doctors and from the DNBC, likely reflecting that the disagreements are random errors (22).

Statistical analyses

All anthropometric measurements were transformed into internal sex-specific Standard Deviation (z)-scores, and for the children, also age-specific z-scores created by (i) forming age-strata, (ii) within each strata, adjusting for the remaining age-variation through a linear regression of age vs. outcome, (iii) collecting the adjusted values at age-specific reference values, and (iv) within each strata, standardizing the values to z-scores. The age strata were based on one (gestational) week intervals for all birth measures, one month intervals for all 5 and 12 months measures, and half a year intervals for the 7 year measures. The z-scores of all anthropometric variables were used as continuous variables. For pairwise comparison of group means, we employed Student's t-test and for comparison of categorical variables we used chi-squared tests. Plots of residuals versus predicted values of the exposure and outcome variables were performed and no noteworthy deviations from linearity were found. Multiple linear and logistic regression models were used to analyse the associations between parental BMI and the child's weight adjusted for height, BMI and waist circumference, and the associations between parental height and child's height at birth, 5 month, 12 month, and 7 years of age. The following covariates were chosen *a priori* and included in the adjusted models: maternal age, socio-economic status, total gestational weight gain, parity, maternal smoking during pregnancy, gestational age, child's age at measurement, and paternal smoking. Furthermore, maternal pre-pregnancy BMI was included in analyses where the paternal BMI was the exposure and vice versa. For the analyses where the outcome was the child's weight or waist, the child's length or height was included as a covariate. Through Wald tests we compared the strengths of the associations between maternal-child and paternal-child anthropometrics, and

between maternal pre-pregnancy-child and maternal post-partum-child associations. With the latter test we assessed differences in pre- and postpartum BMI associations. Due to strong correlations between pre-pregnancy and postpartum BMI of mothers, a variable defining two equally sized groups was generated, which for one half included the mothers' pre-pregnancy BMI and for the other half the postpartum BMI. An interaction term indicating pre- or postpartum BMI times the newly generated BMI variable were included in order to test for differences in associations with respect to pre-pregnancy and postpartum BMI. Moreover, possible effect modification by child sex, maternal smoking during pregnancy, and by the other parent's BMI were tested. With use of logistic regression analyses, the odds ratio for children's overweight by mothers' or fathers' BMI in five groups were analysed, adjusted for the other parent's BMI as well as additional covariates. Moreover, odds ratios for overweight by parents' combined overweight status in four groups were evaluated. All analyses were repeated for both sexes of children. In addition, analyses were repeated by three strata of children, who were either; unexposed to smoke in intrauterine and early life, exposed to smoke only by mothers, or exposed to smoke by both mothers and fathers. Interpretation of the results of the statistical analyses should consider that the sample sizes of the study allow small differences without clear epidemiological significance to be statistically significant at the conventional nominal level of $p<0.05$. All statistical analyses were performed using Stata 12.2 (StataCorp LP, College Station, Texas).

Ethics

The Danish Committee on Biomedical Research Ethics has approved the Danish National Birth Cohort (case no. (KF) 01-471/94). Each participant gave written informed consent at enrollment. The Danish Data Protection Agency has approved the cohort (case no. 2008-54-0431) and the 7-year follow-up (case no. 2004-41-4078). The Danish Data Protection Agency and the Institutional Board Committee of the cohort approved the present study.

RESULTS

Table 1 shows the expected differences between normal weight and overweight children regarding parental and own characteristics of relevance for the comparison between maternal-offspring and paternal-offspring associations in anthropometrics.

Associations with parental BMI

All multiple linear regression analyses showed that both maternal and paternal BMI z-scores were associated with the child's weight and BMI z-scores at birth, 5 months, 12 months, and at 7 years of age. Small changes in association levels were observed after adjustment for covariates (**Table 2-4).** No robust interactions with covariates in the association of parental and child anthropometrics were observed. At birth, mother-child associations in anthropometrics were much stronger than associations between fathers and children; for maternal pre-pregnancy BMI each unit increase in z-score was associated with an adjusted child BMI z-score of 0.143 (95% CI: 0.130, 0.155), whereas for father-child pairs the equivalent slope was 0.017 (95% CI: 0.005, 0.029) per paternal BMI z-score (test for difference, p-value<0.001), see Table 2. These findings imply that for two mothers with a difference of 3.9 kg/m^2 (1 z-score) their newborns will differ by 0.17 kg/m^2, whereas for two fathers with a difference 3.1 kg/m^2 (1 z-score) the children will differ by 0.02 kg/m^2.

At child ages 5 and 12 months, mother-child associations in weight, BMI, and length were lower than at birth, but still somewhat stronger than the father-child associations (Table 2). The differences were slightly strengthened after adjustment for the other parent's BMI and additional covariates. At child age 7 years, associations between mothers' pre-pregnancy BMI z-score and child weight, BMI, and waist z-scores were stronger than during infancy and slightly stronger than

the associations with fathers' BMI z-scores (Table 3). As an example, the results mean that two mothers with a difference of 3.9 kg/m^2 (1 z-score) their 7-year old children will differ by 0.35 kg/m^2, and for two fathers with a difference of 3.1 kg/m^2, the children will differ by 0.26 kg/m^2.

Childhood overweight by parents combined BMI status

The odds ratio for overweight increased with greater parental BMI. Children of underweight parents had lower odds for overweight at 7 years of age than children born to normal weight, overweight or obese fathers and mothers **(Figure 1)**. Moreover, the odds ratio for childhood overweight were very similar across all BMI groups of fathers compared with similar BMI groups of mothers, when adjusting for the other parent's BMI.

The odds ratio for overweight in children born to overweight mothers and normal weight fathers (2.30; 95% CI; 1.99, 2.67) were greater than the odds for children born to an overweight father and normal weight mother (1.96; 95 % CI; 1.74, 2.21), but the difference was not statistically significant (**Figure 2**). Nonetheless, children who had an overweight mother and an overweight father showed about double the odds ratio for overweight (4.35, 95% CI; 3.84, 4.92) than for children with only one overweight parent.

Association with maternal pre- versus post-partum BMI

Associations with maternal pre-pregnancy compared with maternal post-partum BMI and child weight, BMI, or waist circumference at 7 years of age, appeared equally strong in the crude and the adjusted estimates (**Supplemental Table S1**). Tests for differences (through an interaction term, indicating whether it was pre- or postpartum BMI that was included in the model), showed no notable differences. The comparison of maternal postpartum-child BMI associations, with paternal-child BMI associations only revealed small differences, similar to associations with maternal pre-pregnancy-child BMI **(Supplemental Table S2)**.

Associations with parental height

Associations of height z-score measures between parents and children were generally stronger than the associations with weight or BMI z-scores, and they increased in strength from birth through 7 years of age (Table 4). However, similar to the results for BMI, child length and height – they were more strongly associated with mothers' height than with fathers' height, and effect that declined from early life onwards

Gender differences

Differences in associations between boys and girls were investigated. At birth, the measures of the anthropometric associations with girls were generally slightly higher than the measures of associations with boys by both maternal and paternal BMI (**Supplemental Tables S3–S5**). No consistent differences in overweight transmission across same-sex compared with opposite sex parents and children were observed.

Differences by parental smoking status

Analyses stratified by parental smoking status revealed only small difference between maternal-child and paternal-child associations compared with the analyses without stratification (but use of parental smoking only as a covariate) (**Supplemental Tables S6–S10**). Slightly stronger associations were observed in weight, waist, and BMI at all time-points for children born to smokers than to children born to non-smokers.

DISCUSSION

The present study compared the strength of the associations of maternal and paternal BMI with child weight adjusted for length or height at birth and BMI, at 5 months, 12 months and 7 years of age and found that the maternal associations, whether based on maternal pre-pregnancy or postpartum BMI, generally were stronger than the paternal associations. Distinct differences were observed at birth, but the differences became minor at 7 years. The maternal associations for height were consistently stronger than the paternal associations, with no distinct differences by age of the child. The associations were virtually unchanged when the associations were adjusted for a variety of other factors, including the other parents' BMI, which could have confounded the associations. The associations were similar for boys and girls, and for children born to smoking and non-smoking parents.

Our findings are indicative of the expected fetal effects of the maternal intrauterine environment, which is closely related to maternal BMI. The finding that the maternal-paternal difference declined thereafter suggest that the effects of this environment diminished with advancing age of the child. These results correspond to the findings in the Norwegian birth cohort (12), investigating 29,216 family trios with child BMI at birth, and ages 1, 2 and 3 years, except that there were no meaningful difference between maternal and paternal association at 2 and 3 years of age. Thus, the key contrast between these two otherwise very similar studies is the persistence in our study of the moderately weaker paternal-offspring associations than maternal-offspring associations. Assuming that the paternal-offspring associations have not been overestimated in the Norwegian study, the critical question is whether there are methodological reasons for the weaker paternal-offspring than maternal-offspring associations in the Danish study.

Assessment of the effects of assumed non-paternity up to 20% has been carried out in three of the previous studies, which found that this had limited effects on the results (1;7;8). Preliminary statistical simulation estimates of the degree of non-paternity that would be have to be assumed if it should explain the entire observed difference between maternal-offspring and paternal-offspring associations in the present study are unrealistically high (~20% of all births) (see **Supplemental Text)**. However, for several reasons that the probability of non-paternity is very low; First, Danish large-scale register-based studies of mandatorily measured BMI at school ages of both parents (when school children) and their children showed correlations in the later years that were similar for mothers and fathers (13), and this also pertains to the associations with overweight (14) . Second, the choice to participate in the Danish birth cohort combined with the availability of tools for prevention of unwanted pregnancies in that generation make non-paternity less likely. Third, in view of the apparent similarities of the societies and cultures of Norway and Denmark, there seems to be no reason to believe that non-paternity should be more likely in Denmark than in Norway during the overlapping recruitment periods of the two cohorts, and the Norwegian results do not suggest a non-paternity dilution of the paternal-offspring associations.

The other major source of bias worth considering is that paternal-offspring relative to maternal-offspring associations are weakened by greater random and possibly also systematic errors in the reporting of height and weight by the mothers. This may have affected the analyses of both BMI and height. Several of the previous studies, most of which also showed weaker paternal-offspring than maternal-offspring associations, were based on maternal reports only (5-7;9). Self-reported current height and weight has a very high validity and reliability (23), whereas reporting of other peoples' height and weight is less valid and less reliable (24). In theory, there is also the possibility that mothers' self-report and report on their children's height and weight are influenced by the fathers' height and weight, creating correlated errors. Moreover, the use of the maternal report of

the fathers' height and weight during the postpartum period may imply that possible effects of fathers body size during the preceding time on later child growth is missed. It should be noted, however, that using the maternal postpartum rather than the pre-pregnancy anthropometry did not changed the results in any ways affecting the conclusions.

In the Norwegian study, paternal BMI was based on self-reports in 20% of the family trios and maternal reports during their pregnancy in the remaining 80% of the family trios (12). This would lend their results to be susceptible to the same type of biases, but in the subset of 5,755 family trios, where paternal data were available from both sources, the correlation between measured and reported height was high (0.961, 95% confidence interval of 0.959,0.963), suggesting that the procedures used in that study quite effectively ameliorated this form of bias.

BMI is a composite measure of body composition, allowing substantial individual differences in the relative contribution of fat and lean body mass to BMI. In one of the previous studies, body composition of offspring was determined by Dual-energy X-ray absorptiometry (DXA) scanning at ages 9-10 years, and the relation of the offspring fat mass to maternal BMI was somewhat stronger than with paternal BMI, whereas there were no differences in these relationships for lean mass (8). Our results on height would be compatible with the interpretations presented here, as we assume that the paternal-offspring associations have been diluted by maternal reporting errors as discussed above.

Loss to follow-up in the DNBC may cause bias in the estimates but we do not expect the parent-child BMI and height associations to be different among the children not participating in the follow-up. The comparison of the paternal-offspring and maternal-offspring associations may be biased by different effects child growth of specific conditions in either the father or the mother, e.g. type 1 diabetes and hypertensive disorders, that we could not fully account for, but we assume that this sort

of biases are of minimal impact on the overall results due to the relative low frequency of such conditions in this cohort selected without particular focus on health problems from the general population of pregnant women. Moreover, it is important not to adjust the pertinent comparisons for conditions that may be consequences of overweight and obesity and hence possible mediators of the effects on child growth.

We conclude that it seems reasonable to suggest that the intrauterine environment is associated with the growth trajectory of the foetus and the infant, producing a differential impact between parents, but the later parent-child associations in anthropometrics are likely to be driven mainly by the known genetic or environmental effects shared with both parents. The biological mechanisms behind the differences during fetal life and infancy need to be investigated, also because they may have other long-term health implications. The contention that the general increases in maternal pre-pregnancy BMI in recent years may have accelerated the obesity epidemic through specific maternal effects that make the daughters more obese and in turn inducing the same effects on their offspring has limited support, if any, in the evidence now available. The study has been conducted in a population with much lower prevalence of obesity than in several other countries in the Western World, so replications in populations with greater overall prevalence of obesity are warranted.

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Contribution

GDS proposed the study and GDS and TIAS planned it. TIAS provided data-material and TAA and IGC analyzed the data by supervision of LÄ who also performed the analyses on the simulated dataset; TAA drafted the manuscript with help from CSM, and it was critically evaluated by all authors; GDS and TIAS had primarily responsibility for the final content. All authors read and approved the final manuscript.

Conflicts of interest

All authors have declared no conflicts of interest.

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Table 1 Parental and child characteristics according to childrens' weight status at 7 years of age

	All children n=30,566		Normal weight children n=27,624		Overweight children n=2,942		
	Mean	±SD	Mean	±SD	Mean	±SD	
Maternal age (years)	30.7	± 4.1	30.7	± 4.1	30.7	± 4.2	
Parity	0.7	± 0.8	0.7	± 0.8	0.8	± 0.9	***
Pre-pregnancy BMI (kg/m²)	23.3	± 3.9	23.1	± 3.8	25.4	± 4.9	***
Paternal BMI (kg/m^2)	25.1	± 3.1	24.9	± 3.0	26.5	± 3.6	***
Gestational weight gain (kg)	15.2	± 5.3	15.2	± 5.2	15.6	± 6.1	***
Gestational age (days)	282	± 8.7	282	± 8.7	282	± 8.6	*
Birth length (cm)	52.6	± 2.2	52.5	± 2.2	52.9	± 2.3	***
Length at 5 months (m)	68.4	± 2.8	68,3	± 2.8	68.8	± 2.9	***
Length at 12 months (m)	77.6	± 3.1	77.6	± 3.1	78.3	± 3.3	***
Height at 7 years (m)	1.26	± 5.5	125	± 5.4	128	± 6.1	***
Birth weight (g)	3653	± 491	3640	± 486	3779	± 522	***
Child's weight at 5 months (kg)	7.8	± 1.0	7.8	± 0.9	8.3	± 1.1	***
Child's weight at 12 months (kg)	10.3	± 1.2	10.2	± 1.1	11.0	± 1.3	***
Child's weight at 7 years (kg)	24.9	± 3.8	24.1	± 3.0	31.6	± 4.1	***
Child's BMI at 5 months (kg/m)	16.7	± 1.6	16.6	± 1.6	17.5	± 1.8	***
Child's BMI at 12 months (kg/m²)	17.0	± 1.6	17.0	± 1.6	17.9	± 1.7	***
Child's BMI at 7 years (kg/m²)	15.7	± 1.7	15.3	± 1.2	19.2	± 1.6	***
Child's waist at 7 years (cm)	57.0	± 4.7	56.3	± 4.0	63.8	± 5.8	***
Age at 5 months measurement (mean)	5.3	± 0.4	5.3	± 0.4	5.3	± 0.4	
Age at 12 months measurement (mean)	12.6	± 0.6	12.6	± 0.6	12.6	± 0.6	
Age at 7 years measurement (mean)	7.0	± 0.3	7.0	± 0.3	7.0	± 0.3	
Post-partum BMI (kg/m²)	23.4	± 3.9	23.2	± 3.7	25.5	± 4.8	***
	n	%	n	%	n	%	
Socio-economic status							
High	17,273	56.6	15,880	57.6	1,393	47.5	
Middle	11,012	36.1	9,805	35.6	1,207	41.1	
Low	2,209	7.2	1,875	6.8	334	11.4	
P-value						0.02	*
Smoking in pregnancy							
non smoker	23,641	77.3	21,604	78.2	2,037	69.2	
0−10 cig/day	5,458	17.9	4,792	17.4	666	22.6	
>10 cig/day	1,467	4.8	1,228	4.5	239	8.1	
P-value						0.02	*
Sex							
Girls	14,917	48.8	13,298	48.1	1,619	55	
Boys	15,649	51.2	14,326	51.9	1,323	45	
P-value						0.02	*
Fathers smoke (% yes)	30,240	28.4	27,342	27.6	2,898	35.7	***

Data are presented as mean values ± standard deviation (SD) or number of individuals (%).
P-values are two-sided derived from student's t-test or chi2-test, *p-value <0.01, **p-values <0.001, ***p-values <0.0005

Subjects with missing values: parity, n=18; gestational weight gain, n=5,208; birth weight, n=169; birth length, n=256; height 5 months, n=3,512; height 12 months, n=4,984; weight 5 months, n=3,364; weight 12 months, n=4,864; BMI 5 months, n=3,569; BMI 12 months, n=5,082; waist 7 years, n=1,970; age at 5 months, n=4,165; age at 12 months, n=5,999; socio-economic status, n=72, fathers smoke, n=326, Abbreviations: SD, standard deviation; BMI, body mass index

Table 2

Associations between maternal or paternal BMI and the child's weight or BMI at birth, 5 months, and 12 months of age, n =30,566

	Birth weight z-scores	BMI z-scores at birth
	β, 95%CI	**β, 95%CI**
Crude estimate[1]		
Maternal BMI z-scores	0.146, 0.135,0.156	0.120, 0.109,0.131
Paternal BMI z-scores	0.040, 0.029,0.051	0.042, 0.031,0.053
P-value[2]	<0.001	<0.001
Adjusted estimate[3]		
Maternal BMI z-scores	0.102, 0.093,0.111	0.143, 0.130,0.155
Paternal BMI z-scores	0.013, 0.005,0.022	0.017, 0.005,0.029
P-value[2]	<0.001	<0.001
	Weight z-scores at 5 months	**BMI z-scores at 5 months**
	β, 95%CI	**β, 95%CI**
Crude estimate[1]		
Maternal BMI z-scores	0.073, 0.061,0.084	0.068, 0.056,0.079
Paternal BMI z-scores	0.054, 0.043,0.066	0.056, 0.044,0.068
P-value[2]	0.015	0.125
Adjusted estimate[3]		
Maternal BMI z-scores	0.069, 0.058,0.081	0.075, 0.061,0.884
Paternal BMI z-scores	0.012, 0.009,0.016	0.041, 0.027,0.054
P-value[2]	<0.001	0.001
	Weight z-scores at 12 months	**BMI z-scores at 12 months**
	β, 95%CI	**β, 95%CI**
Crude estimate[1]		
Maternal BMI z-scores	0.092, 0.080,0.104	0.073, 0.061,0.086
Paternal BMI z-scores	0.069, 0.057,0.081	0.061, 0.049,0.073
P-value[2]	0.004	0.119
Adjusted estimate[3]		
Maternal BMI z-scores	0.077, 0.064,0.089	0.075, 0.061,0.089
Paternal BMI z-scores	0.046, 0.034,0.057	0.048, 0.035,0.062
P-value[2]	0.001	0.013

[1]Crude estimate included child's gestational age, sex and child's age at follow-up measurement. The other parents BMI is not included in the models

[2]Wald test for difference between maternal-child associations compared with paternal-child associations

[3]Adjusted estimate included child's age at measurement, sex, gestational age, maternal age, parity, socioeconomic status, gestational weight gain, maternal/paternal smoking and BMI (+ child's length for the analyses where the child's weight was the outcome)

Abbreviations: β, beta coefficient; CI, confidence interval; BMI, body mass index

Table 3

Associations between maternal or paternal BMI and the child's weight, BMI, or waist circumference at 7 years of age, n =30,566

	Weight z-scores	BMI z-scores	Waist z-scores
	β, 95%CI	β, 95%CI	β, 95%CI
Crude estimate[1]			
Maternal BMI z-scores	0.208, 0.197,0.219	0.224, 0.213−0.235	0.171, 0.160,0.182
Paternal BMI z-scores	0.178, 0.167,0.189	0.196, 0.185,0.207	0.151, 0.140,0.162
P-value[2]	<0.001	<0.001	0.006
Adjusted estimate[3]			
Maternal BMI z-scores	0.141, 0.132,0.150	0.208, 0.196,0.220	0.131, 0.119,0.144
Paternal BMI z-scores	0.107, 0.098,0.115	0.154, 0.143,0.166	0.107, 0.095,0.118
P-value[2]	<0.001	<0.001	0.016

[1]Crude estimate included child's gestational age, sex and child's age at follow-up measurement. The other parents BMI is not included in the crude models

[2]Wald test for difference between maternal-child associations compared with paternal-child associations

[3]Adjusted estimate included child's age at measurement, sex, gestational age, maternal age, parity, social-economic status, gestational weight gain, maternal/paternal smoking and BMI and child's length in analyses with weight and waist

Abbreviations: β, beta coefficient; CI, confidence interval; BMI, body mass index.

1

Table 4

Associations between maternal or paternal height and the child's length/ height at birth, at 5 and 12 months and at 7 years of age, n =30,566

	Birth length z-scores	Length z-scores at 5 months	Length z-scores at 12 months	Height z-scores at 7 years
	β, 95% CI	β, 95% CI	β, 95% CI	β, 95% CI
Crude estimate[1]				
Maternal height z-scores	0.207, 0.194,0.220	0.263, 0.251,0.275	0.282, 0.270,0.294	0.379, 0.369,0.389
Paternal height z-scores	0.177, 0.164,0.190	0.235, 0.222,0.247	0.263, 0.251,0.275	0.354, 0.343,0.364
P-value[2]	0.012	0.001	0.010	<0.001
Adjusted estimate[3]				
Maternal height z-scores	0.171, 0.156,0.185	0.224, 0.211,0.238	0.244, 0.231,0.257	0.324, 0.313,0.335
Paternal height z-scores	0.143, 0.129,0.157	0.194, 0.180,0.207	0.222, 0.209,0.235	0.301, 0.290,0.312
P-value[2]	0.012	0.003	0.027	0.007

Parental height, child's length and height were analysed with use of internally made z scores values (SD).

[1]Crude estimates included child's gestational age, sex and age at follow-up measurement.

[2]Wald test for difference between maternal-child association of length/height compared with paternal-child association of length/height

[3]Adjusted estimate included child's age at measurement, sex, gestational age, maternal age, parity, social-economic status, gestational weight gain, paternal/maternal height, parental smoking and child weight at the same time as association with height was made

Abbreviations: β, beta coefficient; CI, confidence interval.

1

Figure Legends

Figure 1 OR and 95% CI for child overweight by paternal and maternal BMI. The figure shows child odds ratio for overweight with 95% confidence intervals (CI) by fathers' or mothers' BMI status in four groups; BMI <18.5 (n= 129/1,764); BMI ≥25–<30 (n=12,538/7776); BM I≥30–< 35 (n=1,839/2091), and BMI ≥35 (n=254/688) compared with normal weight BMI 18.5–<25 (n=17,974/29,744) fathers or mothers, adjusted for socioeconomic status, the other parents BMI as well as for gestational age, parity, birth weight, breast feeding, age at follow-up, and smoke status for mothers as well as for fathers. BMIs are from pre-pregnancy BMI measures of mothers and 12 months postpartum information for fathers. The reference line is 1.

Figure 2 OR and 95% CI for child overweight by combined groups of paternal and maternal BMI. The figure shows child's odds ratio for overweight with 95% confidence intervals (CIs) by four groups of parental BMI. 1) Both Normal weight (NW) n=13,272, 2) Father NW and mother overweight (OW), n =9,456, 3) Mother NW and father OW, n= 3,647, 4) Both OW, n=4,743. Overweight include all BMIs ≥25 kg/m^2, collapsing obese and extremely obese mothers and fathers into the overweight group. Underweight parents were excluded from these analyses. Estimates are adjusted for socioeconomic status, gestational age, parity, birth weight, breast feeding, age at follow-up and smoke status for mothers as well as for fathers. Test for sex difference in transmission from an overweight father/normal weight mother compared with odds ratios for an overweight mother/normal weight father showed no difference (p=0.122).